Applied animal behaviour science and animal welfare

6. Applied animal behaviour science and animal welfare: seeking the best balance between our science and its application

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Abstract

Applied animal behaviour science has been closely connected with animal welfare since the formation of the Society for Veterinary Ethology (SVE) in the mid-1960s. It is important to understand the implications of this 'special relationship' both in terms of the positives and opportunities it brings, but also its possible risks and adverse effects on our science. I have used two 'frameworks' in this paper to help understand the relationship. The first is 'Pasteur's Quadrant' proposed by Donald Stokes as an alternative view on science and its application (Stokes, 1997). Stokes rejects the idea that science can only be divided into 'basic' and 'applied' categories and also that the relationship between these is a simple linear progression. He introduced the idea of 'use-inspired basic research' which he exemplified through the work of Louis Pasteur the 'father of microbiology'. The proposition that we can seek fundamental understanding within the context of applying that knowledge, seems especially relevant to our field and interestingly seems to be the direction that science funders are progressing towards. I use three examples of strategic research in applied animal behaviour science, each of which presents a mix of basic science and its application to understanding the animals' 'perspective'. My second 'framework' is provided by the UK research excellence exercise (REF 2014), which I use to revisit the question of the impact of applied animal behaviour science in improving animal welfare. As a part of REF 2014 academic institutions were required to submit Impact Studies, with the aim of demonstrating how a peer reviewed paper progressed towards a measurable impact outside of the science community. I found 27 Impact Studies in the REF database that involve both behavioural science and animal welfare. The results are heartening in terms of the range and extent of the impacts claimed by the studies. I suggest that 'REF-like' exercises conducted in other countries with a tradition of applied animal behaviour science would yield similar results. These two approaches give grounds for optimism for the future based on evidence of strategic science developments within the field, and also that our science is having impact in improving animal welfare. I conclude by emphasising the importance of maintaining the best balance possible between development of our science and its application, something that as a science community we should work on at both a local and global level.

Keywords: applied animal behaviour science, animal welfare, 'Pasteur's quadrant', strategic research, research impact

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6.1 Introduction

Applied animal behaviour science is a set of disciplines (e.g. ethology, psychology and neuroscience) applied to the study of animal behaviour in practical contexts (Lawrence, 2008). There are a number of potential applications of animal behaviour science (e.g. the management of animals, pest control), yet the consideration of animal welfare predominates and overshadows all other potential applications. As other chapters in this book will confirm, the origins of what we now regard as applied animal behaviour science came largely as a response to the publishing of '*Animal Machines*' (Harrison, 1964) and the resulting Brambell Report (Command paper 2836, 1965, referred to as the Brambell report because F.W.R Brambell chaired the committee), on the welfare of intensively farmed livestock. As described in Chapter 1 (Newberry and Sandilands, 2016), a small group of veterinarians felt the need to form a society (the Society for Veterinary Ethology (SVE)) in response to the growing interest in the welfare of farmed animals, no doubt influenced by the emphasis Brambell placed on the importance of behaviour as a means of assessing animal welfare (Command paper 2836, 1965). Early meetings of the SVE (e.g. British Veterinary Journal, 1975) tended to have an even balance between welfare and non-welfare related papers, and the early work of pioneers in the field such as David Wood-Gush was often directed at understanding the behaviour of domesticated animals in its own right, probably reflecting the interest then current in behavioural science and the influence of key scientists such as Tinbergen and Lorenz (Lawrence, 2008).

However by the 1980s the pattern had changed and from then to the present day the vast majority of papers and posters given at SVE (and the International Society for Applied Ethology (ISAE) as SVE became) have had a clear link to animal welfare. The sustained application of applied animal behaviour science to central scientific issues raised in the animal welfare debate has required substantial investment and reflects the level of funding (mainly from public sources) that has been directed towards addressing animal welfare issues in a number of countries since the 1980s. Lawrence (2008) illustrated this trend by describing the increases in output of refereed papers in the field and especially in papers that refer to the application of behavioural science to animal welfare.

It is therefore the case that much of the current work in applied animal behaviour science directed towards animal welfare issues is dependent on the extent of public opinion and hence political interest or concern being directed at animal welfare. This amongst other considerations underlines the importance of understanding the implications of this close relationship in terms of both the positives and opportunities it brings, and its possible risks and adverse effects on our science. Hence it is the implications of this 'special relationship' between applied animal behaviour science and animal welfare which is the subject of this chapter.

6.2 The balance between science and its application

Behind the question of how we should understand and deal with the consequences for applied animal behaviour science, of the strong focus on animal welfare issues, lie complex

questions about scientific discovery and the balance between what can be referred to as 'basic' and 'applied' research. In '*Pasteur's Quadrant*', (see Stokes, 1997 and Figure 6.1) it is proposed that the division between basic and applied research originates from an influential report on science discovery and application (Bush, 1945, cited from Stokes, 1997). Stokes (1997) suggests that this dichotomy between basic and applied research prevailed during the rapid expansion of scientific research that occurred in the aftermath of World War II, and had a substantial impact on public policy underlying decisions on research funding, for example shaping US government policy on research funding in the post-World War II period (M.H. Armacost in the Preface to Stokes, 1997). In the UK, the 'Barnes Report' (commissioned by the UK government and published in 1988), proposed that a substantial amount of agricultural research previously funded from public funds should be classified as 'near market' and either funded by industry or terminated (Read, 1989). This led to a contraction of the UK agriculture research base, the after effects of which continue to the present time, and also to publicly funded research being more tightly tied to specific (short-term) policy interest, as opposed to longer-term strategic issues (Murphy-Bokern, 2008).

Underlying the decision over who should pay for applied research is an economic debate about the role of the State in the application of science and what is now referred to as innovation. The position taken by the Barnes report was that as the private sector benefited from near-market research then it should pay. However this view has been challenged partly on the basis of evidence that the private sector often only invests once the State has made high-risk research investments (Mazzucato, 2013) and also because the inter-relationships between the private sector and the State in research is complex

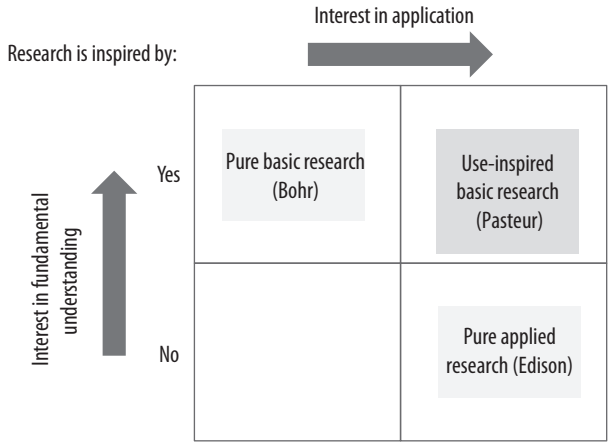

Figure 6.1. Pasteur's Quadrant redrawn from Stokes (1997, p. 73). Stokes used the work of Niels Bohr (the early 20th century atomic physicist) to exemplify what he referred to as Pure basic research (referred to in the text as basic research); the work of Thomas Edison (inventor) to exemplify Pure applied research (referred to as applied research) and the work of Louis Pasteur (the father of microbiology) to exemplify Use-inspired basic research (referred to as strategic research).

and easily perturbed (Read, 1989). More recently in a number of countries including the UK there has been a growth in what are referred to as 'public-private partnerships' where there is a shared funding of research and where industry is permitted to 'pay' part or all of their share through 'in-kind' contributions (e.g. access to animals or data; see Innovate UK as an example of this approach).

As an alternative view, Stokes (1997) proposed that we can recognise three categories of research (Figure 6.1):
1. Pure basic research (Stokes exemplified this category of research through the work of Niels Bohr, the early 20th century atomic physicist);
2. Pure applied research (exemplified by the work of Thomas Edison, inventor);
3. Use-inspired basic research (exemplified by the work of Louis Pasteur the 'father of microbiology').

What is different about Stokes' (1997) argument is that he sees a resolution to the supposed tension between pursuit of science and application through what he calls 'use-inspired basic science'. Another term used in this context is 'strategic research' that also implies basic research conducted in the context of discovery of uses and applications, and I will use this term mainly for convenience. Relevant to the future development of applied animal behaviour science, Stokes suggests that, as in the case of Pasteur, it is possible to carry out what might otherwise be regarded as basic science but with a focus on an applied outcome (the 'best of both worlds'). Furthermore, Stokes proposes that the relationship between basic research and application is rarely linear and we need to see science and its application in a more interactive and dynamic way (Figure 6.2 for Stokes's interpretation of a 'dynamic' interaction between science and application). It could be

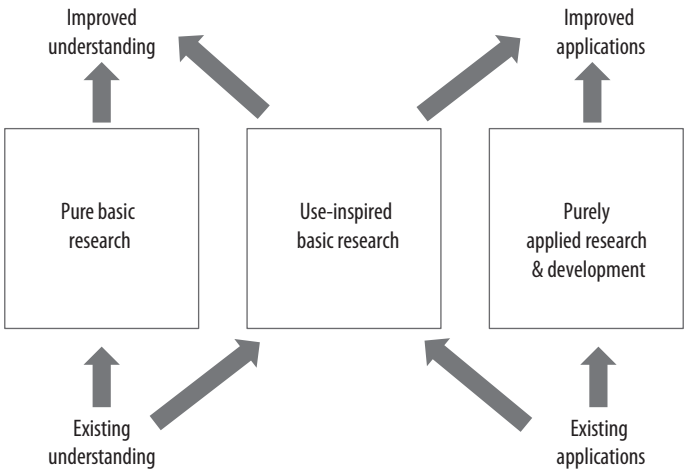

Figure 6.2. A 'dynamic model' of interactions between different categories of science redrawn from Stokes (1997, p. 88) as an alternative to the 'traditional' linear model of progression from basic science to its application.

argued that Stokes's proposition is in the process of being re-invented, as government funding of research (including basic research) is to an extent required to have 'research impact' (more on this later).

Hence, consideration of the influence of animal welfare on the development of applied animal behaviour science can be seen in terms of the best balance between scientific enquiry in its own right versus the application of our science, but also about how we promote research that sits in the 'sweet spot' occupied by the likes of Pasteur. In the remainder of this chapter I will explore these considerations from the perspective both of developing our science and of improving its application, and the interactions between these two objectives.

6.3 The impact of animal welfare on the development of applied animal behaviour science

6.3.1 The 'positive side'

Arguably the most important positive resulting from the focus on animal welfare has been the science and innovation it has led to with respect to assessing the 'animals' perspective'. The application of behavioural science to understanding of animals' inner psychological or mental state has had something of a chequered history in science (see Lawrence, 2008, pp. 3-4 for a brief resumé). It follows from the Brambell Report and the Five Freedoms (formulated by the UK Farm Animal Welfare Council; FAWC, 1979) that animal welfare is about both physical and mental well-being and hence any science directed at animal welfare needs to address both of these elements. The position of many applied animal behaviour scientists was most clearly laid down by Duncan (1993) in a paper entitled 'Animal welfare is to do with what animals feel', and despite misgivings within the wider field of animal behaviour (e.g. Kennedy, 1992; MacPhail, 1998) applied animal behaviour scientists have set about establishing scientific approaches to understanding animals' mental states. I want to highlight three examples of approaches which appear to display the characteristics that Stokes had in mind when he coined the category of use-inspired basic research; these are intended as examples and not an exhaustive list and others I am sure could produce their own examples to fit the strategic research category.

1. *Preference testing and derivatives.* The first of these approaches to emerge was championed by Marion Dawkins (1980) in her book '*Animal Suffering: The Science of Animal Welfare*', which promoted the use of animal 'preference testing' and study of animals' 'choices' as a method of objectively assessing animals' motivational priorities and by inference, their experiences. In further refinements of preference testing, methods were developed for estimating the 'cost' animals were 'willing to pay' to access different rewards once preferences had been established (e.g. estimating cost based on the willingness of the animal to press a device such as a key or panel (Dawkins, 1990)). This approach can be used to derive what are referred to as 'demand functions' for behaviours that display the characteristics of being 'elastic' (where the animal 'demands' less of a resource as the 'price' increases) or 'inelastic' (where the animal's demand for a resource is relatively unaffected by the price (Matthews and Ladewig,

1994)). The link to the economic analysis of supply and demand (which analyses human demand in relation to price) resulted in the approach often being referred to as the 'consumer demand' approach to assessment of behavioural needs (Dawkins, 1990). A study using the consumer demand approach to examine the motivation of farmed mink for access to water was published in Nature (Mason *et al.*, 2001), and was the first applied animal behaviour science paper to achieve this distinction.

Both preference testing and consumer demand have also been used in the wider behavioural sciences; preference testing has been used to assess habitat preferences (e.g. Morris *et al.*, 2001) and consumer demand approaches have been used to study the characteristics of motivational states believed to underlie behavioural expressions (e.g. Hogan and Roper, 1978). However in its application to animal welfare, Dawkins and others have assumed that preference and the 'cost paid' equate to animals' emotional states (or feelings) and to what animals 'want' or 'don't want' (Dawkins, 2008).

More recent development of preference testing involves the study of the associations between animals preferences and so-called 'welfare indicators'. Research on welfare indicators has arisen as a result of the growing interest in assessing welfare under practical conditions (e.g. on farms; Botreau *et al.*, 2007), where welfare indicators ideally should be reliable (e.g. show small variance between observers or assessors), valid (be a validated measure of the animals' experience) and also practical (taking account of constraints such as time availability). Of these three requirements the validation of welfare indicators is the most challenging, and it can be argued that current welfare indicators are selected more on the basis of practical considerations rather than for validity (see FAWC, 2005, Appendix A). Christine Nicol has argued that one approach to validation of welfare indicators is to study their association with animals' environmental preferences. Nicol *et al.* (2009) found that whilst some putative welfare indicators were associated with birds' positive choices (whatever those choices were), other indicators were not associated with environmental preferences, which suggests that this approach may have the capability of discriminating between indicators in terms of their relevance to the animals' experience. Current work (Davies *et al.*, 2015) is exploring the associations between animal decisions (which lead to expressed preferences) and so-called 'somatic markers' (e.g. heart rate), adding to our knowledge of the biology that links animal preferences with potential welfare indicators.

2. *Cognitive bias and other approaches developed from human psychology.* My second example also illustrates how approaches developed in one field (here studies of human cognition and emotion) were innovatively 're-configured' for use in applied animal behaviour science for assessing animals' 'mental state'. Alain Boissy, Isabelle Veissier and co-workers (e.g. Désiré *et al.*, 2002), proposed that animal emotions can be studied through presenting to animals stimuli with characteristics known to induce specific emotional states in humans (i.e. the study of cognitive processing on emotional expression). For example Boissy *et al.* (2011) showed that ear posture in sheep could be consistently related to different emotional contexts where the emotional context was defined by its 'cognitive characteristics' (e.g. the suddenness or unfamiliarity of the triggering stimulus).

An alternative approach proposed by Mike Mendl, Liz Paul and co-workers was based on the reverse process, where an underlying affective (emotional) state can influence how we process information about our environment (e.g. depressed or anxious people tend to judge ambiguous stimuli more negatively (Mathews and Mackintosh, 1998)). In the first study of what is now referred to as the 'cognitive bias' approach, rats were tested for their response to ambiguous stimuli having experienced different housing prior to the testing; the results (again published in Nature) indicated that rats housed in 'unpredictable housing' (predicted from previous work to induce mild depressive symptoms) showed a negative 'pessimistic' bias when responding to ambiguous stimuli (Harding *et al.*, 2004). Since its first use, cognitive bias has been widely taken up in applied animal behaviour science. In a Web of Science® search I was able to find over 20 experimental studies with more than five citations in studies ranging from primates to honey bees. The study on bees (Bateson *et al.*, 2011) which demonstrated that a negative event (being shaken) resulted in more 'pessimistic choices' in response to ambiguity, raised the interesting and somewhat perplexing question of how to interpret 'pessimistic' or 'optimistic' biases in 'lower animals' (Mendl *et al.*, 2011).
It seems likely that human cognitive studies will foster both further innovation in applied animal behaviour science and also theoretical developments. For example, along similar lines to cognitive bias, the 'response to reward loss' approach, also based on human cognitive studies, argues that animals in a negative emotional state will show more enhanced responses when experiencing reward loss (Burman *et al.*, 2008). In addition Mendl and Paul have developed conceptual frameworks to understand and interpret results from work on animal emotions (Mendl *et al.*, 2010; Paul *et al.*, 2005) providing an example of strategic research 'feeding back' to basic research.

3. *Qualitative behavioural assessment.* My last example of science and innovation in applied animal behaviour science in the context of assessing animals' mental state is qualitative behavioural assessment (or QBA), developed by Françoise Wemelsfelder and colleagues. I had personal involvement in the development of QBA, working with Françoise during the early 1990s at what was then the Scottish Agricultural College (SAC). QBA arose from Wemelsfelder's position (part philosophical and part biological) that it can be legitimate to study animal behaviour from a qualitative perspective, and indeed that it may be essential to do so, in order to capture the subjective aspects relating to mental state that are of concern in animal welfare (Wemelsfelder, 2012). The result of this thinking led Wemelsfelder to develop an approach to the recording of animal behaviour that focuses on expressive quality of the behaviour as opposed to the physical characteristics that are normally used in behavioural data collection. An innovative step in the approach was provided by the collaboration between Wemelsfelder and Tony Hunter. Hunter was a bio-statistician who specialised in sensory food testing and suggested an approach to qualitative assessment of animal behaviour through free-choice profiling (FCP). FCP allows observers to develop and use their own qualitative terminology which, combined with a statistical analysis (Generalised Procrustes Analysis), provides an approach to collect and analyse qualitative descriptions of animal behaviour (Wemelsfelder *et al.*, 2001). Early tests of the approach, conducted using videos of individual pigs interacting with a person in their pen, with observations being made by observers using their own

qualitative terms, demonstrated significant agreement between observers, suggesting that observers' assessments of the pig were reliable (Wemelsfelder *et al.*, 2001). Since then there has been research looking further at issues of observer reliability (Wemelsfelder *et al.*, 2012) and validity (Rutherford *et al.*, 2012; Stockman *et al.*, 2011), and considerable interest in the application of QBA to on-farm assessment of welfare (Wemelsfelder and Mullan, 2014). QBA was also incorporated into the WelfareQuality® assessment protocols for the assessment of positive welfare and has been used in a number of studies testing the efficacy of the WelfareQuality® protocol (Vries *et al.*, 2013).

However, QBA has raised tensions in applied animal behaviour science (acknowledged by Wemelsfelder, 2012). By openly acknowledging the qualitative nature of the approach, QBA can be seen as being 'more about the observer than the animal' and at risk of being anthropomorphic and hence unreliable. Despite these concerns my view is that there is a growing acceptance of the reliability, validity and utility of QBA within our field. This is founded upon results from peer reviewed papers, the experience of using the approach and also perhaps by the realisation that, as with the distinction between basic and applied science discussed earlier, the distinction between objective and subjective science is more blurred than we may realise or acknowledge.

6.3.2 The 'negative side'

I have just argued that welfare provides plenty of scope for strategic research and I have given examples of where, in my view, applied animal behaviour science has risen to this challenge. On the opposite (negative) side it can be argued that the focus on welfare issues has curtailed development of applied animal behaviour science, as we focus too much on the application and not sufficiently on the development of our science. Certainly one criticism that the applied animal behaviour and welfare 'community' has faced in the UK, is that our science is too often derivative and lacking international excellence, albeit perhaps unfairly given my previous section!

One obvious problem is the availability of funding to support basic/ strategic science in our field (which links back to science funding policy in relation to basic and applied research). Examples from my own research experience where funding has influenced the balance between basic and applied research includes work we carried out on stereotypic behaviour in closely confined sows. The Brambell Committee had voiced their concern over such confinement (Command paper 2836, 1965) and it became something of a hot topic in research in the 1980s and 1990s (Rushen *et al.*, 1993). A series of research papers from different groups pointed to the combination of food restriction (and elevated hunger and foraging motivation) and the thwarting effects of close confinement on that foraging motivation as strong contributing factors in the development of stereotypies in sows (Lawrence and Terlouw, 1993). However, the research did not provide much illumination on more fundamental questions about the relationship between stereotypic behaviour and welfare. Nevertheless, when the UK phased out the use of close confinement systems for pregnant sows in 1999, UK research on sow stereotypies ceased, despite these fundamental questions remaining. Another example comes from our work aimed at

developing indicators of stress in farrowing sows. We had proposed that opioid-inhibition of oxytocin could be used as a sensitive indicator of stress in the farrowing sow (based on Lawrence *et al.*, 1992). However when we analysed blood samples from sows farrowing in different environments, we found no effect of environment on circulating oxytocin and vasopressin (Lawrence *et al.*, 1995). We did however find that the opioid antagonist naloxone increased circulating levels of both oxytocin and vasopressin, suggesting that a degree of opioid inhibition of these reproductive hormones is part of a normal parturition (Jarvis *et al.*, 2000) (Figure 6.3). However our funding at the time, which was more directed at applied questions, did not allow us to investigate the more basic question of the function of this opioid-inhibition (e.g. whether it played a role in preventing depletion of the finite stores of pituitary oxytocin (Russell *et al.*, 2003)). Of course work ceasing in one research group or even in one country does not preclude others working in the area; regarding the links between stereotypies and welfare, other scientists found new animal models to address these questions (e.g. the work of Joe Garner and Georgia Mason (2002)). Furthermore, the finding that stereotypies were related to food restriction in some species, helped to trigger a considerable body of research on the welfare impacts of food restriction which still continues to this day (D'Eath *et al.*, 2009; Dunn *et al.*, 2013). However, funding can clearly constrain individuals or groups from pursuing continuity of research on specific issues, due to changing funding policies and strategies.

From a UK perspective, over the last 10 years there have been rather dramatic changes in the funding of applied animal behaviour and welfare research which are undoubtedly causing adjustments in the type of work being funded. Previously government departments responsible for welfare policy funded a considerable amount of welfare-related research (much of it involving elements of animal behaviour); the research ranged across the spectrum from more basic to more applied and policy related. This source of funding has

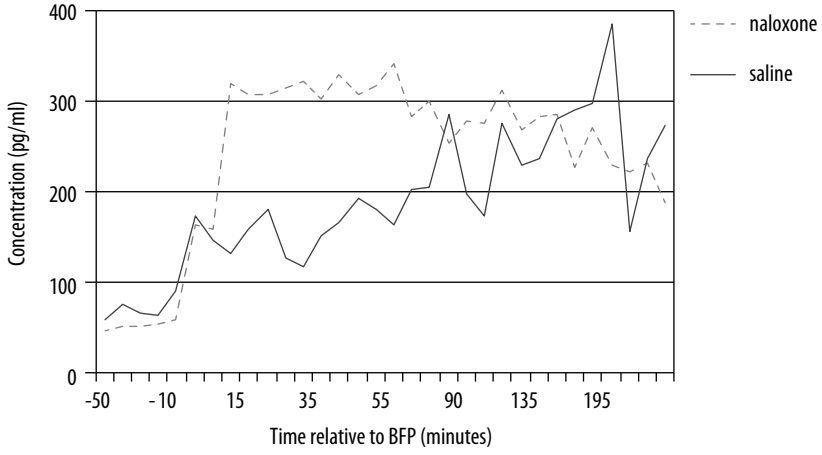

Figure 6.3. The pattern of plasma oxytocin (ng/ml) in sows as a response to administration of naloxone or saline. BFP = birth of the first piglet. There was a significant increase in oxytocin in the early stages of parturition in sows receiving naloxone (redrawn from Jarvis et al.*, 2000).*

now almost completely ceased. Today in the UK applied animal behaviour and welfare research has two main types of funding available: (a) 'Research council' funding: this is highly competitive and for research to be funded requires that it is deemed to be of high international excellence; this therefore tends towards the funding of more basic research although there is now also a requirement to illustrate how the research will have impact (e.g. see BBSRC, 2012); (b) Innovation funding: this is at the applied end of the spectrum and in the UK is now intended to be led by commercial interests, and likely success in implementation (e.g. product development) is a key element for gaining funding (e.g. Innovate, UK). In the UK, therefore, the major difference to the past is the lack of funding for strategic research to bridge between basic and applied research, similar to the work I described above as examples of strategic research. From what I know of other countries it seems that they vary in the extent to which they have funding to cover strategic research. In my view there would be benefit in a formal analysis of why these important changes have and are taking place as they are likely to have an impact both on the amount and type of welfare related research activity and also on impact in relation to improving animal welfare.

Funding considerations aside, we can also question whether the focus on welfare issues reduces the extent of scientific enquiry. For example, are researchers more focused on addressing practical issues rather than trying to understand underlying principles or to 'break through' with new scientific discoveries? This concern was raised by Dawkins (1997) and Rushen (2003), both pointing to the risks of succumbing to political pressure to provide quick answers, and hence avoiding addressing important and complex issues such as how we validate welfare indicators (see discussion above). In the examples given above this was not the case and all three areas described have generated results and theoretical writings which I think, by any measure, make significant and deep contributions to animal biology and the understanding of how to assess animals' mental states (Dawkins, 1990; Mendl *et al.*, 2010; Wemelsfelder, 2012). But it is a question for the field in general of whether there should be more encouragement of theoretical developments.

We can also question whether a focus on welfare leads researchers to intrinsic biases in the conduct and reporting of our science. For example, changes to housing are described as enrichments prior to there being any evidence that they have a positive relevance for the animal. In the other direction, treatments may only be imposed that are likely to occur in practice, thus not presenting the animal with true positive controls and giving little indication of the full spectrum of the animals' responses.

In summary, with respect to the influence of animal welfare on the development of applied animal behaviour science, I suggest that: (a) animal welfare provides many opportunities for basic science and its innovation; (b) it is possible to find examples from our field that fit into 'Pasteur's cell' of being excellent strategic research and I have given three examples (others I am sure could produce their own); (c) my examples illustrate that more than one scientist and often more than one group is responsible for a breakthrough or step-change, and that the process through which the science is developed and then used is dynamic and rarely linear (as suggested by Stokes (1997)); (d) it is also possible that the focus on welfare has negative impacts on the development of applied animal behaviour science

because: (1) there are funding constraints (e.g. lack of funding for strategic science); (2) there is insufficient attention given to theoretical developments in the field; and (3) there are inherent biases in the way we approach our science that stem directly or indirectly from our focus on animal welfare.

6.4 The impact of applied animal behaviour science on animal welfare

Given the close relationship between applied animal behaviour science and animal welfare it is perhaps not surprising that the field has had an interest and even a concern about the impact of our science in terms of improving animal welfare with a number of authors debating the extent to which applied animal behaviour science has made a difference to animal welfare (Dawkins, 1997; Millman *et al.*, 2004; Rushen, 2003). As these authors pointed out, the question of assessing the impact of research is complex.

The topic of research impact is currently of considerable policy interest. As pointed out above, research councils in the UK have introduced the requirement that research be accompanied by statements of 'Pathways to Impact', and this emphasis on research impact is even more keenly emphasised in innovation funding platforms (e.g. Innovate UK). In Scotland, Scottish Government funding of agricultural, food and rural research is now strongly influenced by the concept of research impact, where the funded research is aimed at building 'a platform of knowledge that strengthens policy and contributes to the delivery of national outcomes' (RESAS, 2015). In reporting research activities to the Scottish Government's Rural and Environment Science and Analytical Services Division (RESAS), we not only cover traditional metrics (e.g. numbers of papers, amounts of external funding) but also our interactions with policy makers, with industry and with other stakeholders, including the public. Value is placed on these 'knowledge, transfer, exchange' activities where there is evidence that they have had impact (e.g. where scientific knowledge has been incorporated into policy or used by industry).

Furthermore, funding to universities in the UK is partly distributed on the basis of an assessment of research quality. Previously this was achieved by assessing the quality of individual outputs (usually peer reviewed papers). However in the current round an additional requirement was to provide impact case studies that demonstrate how a piece of science has achieved impact (see Research Excellence Framework (REF), 2014). The format was for impact studies to start with a peer reviewed piece of work (the initial paper which for REF 2014 had to have been published no earlier than 1993 and which had to be of a stated quality (2* or above on the REF Assessment criteria)); other papers could be quoted in support of the study. The impact case study had to demonstrate how the science led to a specific and measurable impact. However, note that this presumes the application of science as a linear progression as opposed to the more dynamic process suggested by Stokes (1997). The case study also had to be backed-up with corroborating sources, such as letters from policy contacts or commercial partners.

These impact case studies are now publicly available on the REF web-site (search REF impact case studies) and they provide an opportunity to explore the impact of our science in improving animal welfare. It is necessary to point out that the specific scores given to impact statements are not available. However, each submitting institute will have gone through an extensive, competitive screening process and for an impact statement to be found on the REF database suggests that at least the institute concerned (often assisted by external advisors) believed it to have had measurable impact. What can also be found are the references underpinning the study and where available an Altmetric score, which provides a record of all online discussions and shares of the research (http://www.altmetric.com/audience/researchers/).

I have searched the REF database using various appropriate terms and the results are shown in Table 6.1. I found 27 impact case studies that appear to fall within the scope of applied animal behaviour science and animal welfare. We could ask whether this number is more or less than we would expect. I found this hard to judge. It is a very small proportion of the over 6,000 submitted impact case studies but the UK applied animal behaviour and welfare community is also very small (I suggest less than 100 'full time equivalent' staff). The distribution is perhaps not surprising, with over 50% of the studies coming from farm animals (where historically funding has been allocated); nonetheless there is also work on laboratory, companion and captive animals. Looking at the areas covered, I classified eight (>30%) as being on pain related issues, five (~20%) on aspects of housing, and smaller numbers on handling (3), transport and slaughter (3), human-animal interactions (2), well-being (1) and applications of behaviour recording (including automation of behaviour recording (4). Some Impact Studies overlapped between areas but I have not tried to capture this.

I have also provided an indication of the impact being claimed, with brief quotes from the REF (2014) web-site (Table 6.1). From this collation I make the following observations.

- This seems a useful resource with excellent search functions and could be used within our field to provide examples and perhaps spread best practice on making our science more impactful. For example, to assess the impact of research more fully and efficiently, data on impact (e.g. numbers of animals affected) needs to be collected during the process rather than retrospectively.
- There is a very broad and impressive range of impacts claimed here: influencing UK, European Union (EU), and other (e.g. commercial, charity) policy making, including forming legislation; changing husbandry practice (e.g. handling of rodents, pain relief in various species, management of lameness in cows); changes to housing (e.g. aerial perches for hens, water provision for ducks, loose farrowing for sows); policy and practice relating to transport and slaughter; use of behavioural recording (e.g. cognitive testing in rodents, oestrous detection in cows) and public engagement (e.g. the Living Links exhibit).
- This range of impacts illustrates the many and interacting routes that science can follow on its path to impact. For example the study 'Minimising heat and other stresses during animal transportation' (Edinburgh) has informed scientific opinion as expressed by the European Food Safety Authority, EU and UK legislation, and codes of practice followed by hauliers and vehicle design.

Table 6.1. Relevant impact studies from the UK Research Assessment Exercise (REF 2014) downloaded from http://www.ref.ac.uk/; key words used were 'animal welfare', 'animal behaviour' and 'animal cognition' (searched together and separately). Shown here is a sample of 13 studies selected from among 27 Impact Studies that lie within the scope of applied animal behaviour science, the submitting institute and if available the named scientist(s) and a quote taken from the study to indicate the impact being claimed (phrases in italics added for clarity).

Impact study, organization (scientist)	Quotes on proposed impact
Transforming the welfare of commercially-reared poultry – Oxford (Dawkins)	'findings in relation to stocking densities for broiler chickens influenced the 2007 EU Broiler Directive ... has had a major impact on the industry ... For ducks, research examined the provision of water ... and identified solutions'.
Improving animal welfare through effective pain assessment and alleviation in laboratory rodents and rabbits – Newcastle	'research changed policy and practice relating to the provision of pain relief to rodents and rabbits. This has impacted on up to 35 million animals worldwide during the REF period'.
Pain research improves welfare of fish – Edinburgh (Braithwaite and Gentle)	'UK, EU and RSPCA animal welfare policies and guidelines have been informed by the research'; (numbers affected) ... millions of farmed fish in the EU'.
Whole-house gassing improves the welfare of birds requiring culling during a major disease outbreak and is now adopted by Defra – Edinburgh (Sparks and Sandilands)	'Policy Impact: Developed a humane culling method for large numbers of poultry in preparation for an outbreak of a notifiable disease such as avian flu ... adopted by Defra'.
Aerial perches improve the welfare of laying hens and are now recommended by the European Union – Edinburgh (Sparks, Sandilands and Green)	'research informed welfare guidelines impacting upon housing of around 200 million laying birds in the EU ... work has been adopted in EC regulations, and they are pushing all EU member states to ensure all their producers install aerial perches over slatted surfaces.'
Minimising heat and other stresses during animal transportation improves animal welfare and has driven EU legislation – Edinburgh (Mitchell)	'~60 billion animals are transported world-wide each year...definition of optimum transport environments has underpinned improved transport vehicle design and ... development of regulations'.
Loose-farrowing systems Improve the welfare of the sow whilst protecting the welfare of the piglet and have superseded the farrowing crate, now banned in three countries – Edinburgh & Newcastle (Baxter, Jarvis. Lawrence, Roehe, Edwards)	'This body of research has provided a fundamental platform of robust scientific evidence about the welfare detriments of crated sows whilst also working on solutions to improve piglet survival that are translated directly to the industry, thus advancing the welfare of both the sow and piglets.'
Effect of electronic training aids (E-collars) on pet welfare – Lincoln	'has stimulated debate and action by both anti-collar campaigners and the manufacturing industry; e.g. industry bodies are now working with Government to produce guidelines to reduce risks identified'.
Improvements in egg quality and hen welfare have enhanced productivity in the egg industry – Glasgow	'research on the long-term health and welfare implications of infrared beak trimming influenced UK policy debate, preventing a ban on beak trimming (due to be enacted in 2011) that would have exposed 35 million laying hens to potential pecking injury or death, as well as costing the industry an estimated £4.82-£12.3 million annually'.
Advancing clinical assessment of acute pain in companion animals – Glasgow	'researchers have been instrumental in developing international pain guidelines with the World Small Animal Veterinary Association, which represent more than 180,000 veterinarians worldwide...has promoted awareness of pain management in companion animals'.

Table 6.1. Continued.

Improved dairy-cattle welfare and reduced financial losses result from Bristol research into lameness – Bristol	'Dairy-cow herds in the UK and overseas, together with the dairy farming industry, are benefiting from strategic animal-husbandry changes and lameness-control programmes underpinned by research undertaken at the University of Bristol since 1997'.
Welfare of millions of laying hens across Europe transformed by the introduction of enriched cages – Bristol	'Hundreds of millions of laying hens in the European Community are now kept in enriched cages ... Research undertaken at Bristol University provided much of the evidence base for the full implementation of the relevant European directive'.
Electronic monitoring of dairy herds increases efficiency and reduces costs for UK and EU farmers - Strathclyde	'decision support platform combining artificial intelligence with low power wireless sensor technology, which was capable of alerting farm staff to animal conditions (changes in behaviour) ... more than 250 farms in the UK and Europe have adopted the technology'.

- A number of the studies illustrate the length of time it takes for science to evolve and have a measurable impact (Dawkins, 1997; Lawrence, 2008). For example the initial paper for the study 'Welfare of millions of laying hens across Europe transformed' (Bristol) was published at the cut-off date of 1993 (Sherwin and Nicol, 1993; Table 6.1 and REF, 2015 for similar examples). Interestingly there are also examples that show a much faster route to application; for example the technology based study 'Electronic monitoring of dairy herds' (Strathclyde) has an initial paper published in 2009 (Sasloglou *et al.*, 2009).
- There is some continuity here between the examples of applied animal behaviour science-led approaches to welfare assessment (see above) and these impact studies. For example, the studies 'Transforming the welfare of commercially-reared poultry' (Oxford) and 'Welfare of millions of laying hens across Europe transformed' (Bristol) both refer to the use of preference and choice testing (Jones *et al.*, 2009; Sherwin and Nicol, 1993).
- There are also examples where the science has come from outside the normal range of applied animal behaviour science. For example, the technology driven applications on automating behavioural recording or cognitive testing ('Actual Analytics Ltd: automated processing of video data' and 'Touch screen based cognitive testing for rats and mice'); also the 'Living Links to Human Evolution' Research Centre', which stems primarily from research into primate behaviour and ecology.
- Lastly, on a cautionary note, this exercise does not seem to fully address the difficulty of assessing science impact. For example, the contribution of individual papers (within the context of the wider literature and other information) to a specific impact remains a complex issue and (in my view) difficult to define. Also given that this is a competitive process the submitters of the Impact Statements are unlikely to be unbiased when assessing the actual impact of their work.

In summary, the question of how impactful applied animal behaviour science has been to improving animal welfare now has wider relevance given the increasing interest and

attention being given to science impact. The UK research assessment exercise (REF) has provided us with a process and data for reviewing some of our science impacts. The results of my survey of the impact case studies submitted to the REF are, I suggest, heartening in terms of their range (across species and issues) and their extent (e.g. as assessed through influence on policy, forming of legislation, economic return on investment). Although this is UK based, I would suggest that similar exercises conducted in other countries with a tradition of applied animal behaviour science would yield similar results. The submission of impact case studies from other disciplines points to the need for applied animal behaviour science to continue to seek cross-discipline collaborations, including with commercial science and technology groups. It will be interesting to see whether in future more of the strategic research in applied animal behaviour science (such as my earlier examples) will find its way to having meaningful impact, thus justifying the label of 'use-inspired basic research' (Stokes, 1997).

6.5 Conclusions

In this paper I have applied two 'frameworks' to explore the relationship between applied animal behaviour science and animal welfare. I used 'Pasteur's Quadrant' provided by Stokes (1997) to discuss the relationships between science and its application, and the UK REF exercise to assess the impact of our science on improving animal welfare. 'Pasteur's Quadrant' seems a particularly relevant approach for a field such as applied animal behaviour science, which has such a close alignment to an applied issue (animal welfare) and where there is a need to consider the balance between developing the science and its application. Previous concerns about how impactful our research is (e.g. Dawkins, 1997) have lacked easily accessible evidence with which to assess impact. The REF database (with some obvious limitations) helps to fill that gap.

Using these frameworks I have emerged reasonably optimistic for the future. My optimism is based on two foundations: (1) the examples of 'use-inspired basic' or 'strategic' research (of which I am sure there are others than the three I chose to highlight), that indicate the scientific strengths within the field; (2) the examples of science impact that I collated from the UK's REF database. Again we can assume that this is just a sample of such impacts that would be substantially increased if this type of exercise was extended to other countries.

I hope that this chapter has helped to illustrate the importance of finding the best possible balance between development of the science and its application to animal welfare. With too little science development, we risk running out of novel developments to apply, and with the likely increasing need to apply to basic science funders, there is a potential drying up of research funding. With too little application we similarly run the risk of losing research funding (with the increased emphasis on impact), and more importantly not addressing the many pressing animal welfare issues in the field. Of these two risks my personal inclination is to be concerned more with there being sufficient science development in our field, not least because winning funds to pursue basic or strategic science is challenging.

I would suggest that as a science community we should consider more what can be done to maintain the best balance between developing our science and its application to animal welfare issues, and to encouraging more 'use-inspired basic' or 'strategic' research. This could happen at a global level (e.g. with ISAE taking the lead) or with more regional attempts to boost discussion on the balance between developing our science and its application. One starting point could be to collate further examples of strategic research and impacts to use as examples for ourselves, and in wider representation of the contribution of our field to science and animal welfare.

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